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Instruction Manual

Model 872
Wide Range Resistance Meter

1998

1.0 Introduction

Many applications require the measurement of resistance or resistivity over a wide range. The Model 872 Wide Range Resistance Meter is a battery or AC powered laboratory instrument that is capable of measuring resistance or resistivity over the range of 10^1 to 10^{13} ohms utilizing a user selected test voltage of either 10 or 100 volts. Measurement accuracy is ±2% over the 10^1 to 10^7 ohms range and better than ±5% over the 10^8 to 10^{12} range.

The Model 872 can be used with any type of resistance or resistivity test probe or test cell. It is an ideal instrument when used with the ETS Model 803 Series Resistance/Resistivity Probes, Model 850 Surface Resistance Probe and Model 805 IC Tube Resistivity Test Fixture for measuring the resistance/resistivity requirements specified in ASTM D-257, EIS-541, NFPA 99, EOS/ESD STD-4 S4.1, STD-7 S7.1 and STD 11.1 S11.1, DS11.2 ASTM F 150 and applicable DOD Standards.

Certain specifications such as ASTM F-150, NFPA 99 and certain DOD Standards also require test voltages of 500 volts. Normally, higher test voltages will result in lower resistance readings. Hence, a "PASS" indication utilizing 10 or 100 volts will generally meet any resistance requirements specified at the higher voltages.

2.0 Equipment Description

The Model 872 Wide Range Resistance Meter is a precision instrument designed for bench top applications. It can be operated from either two (2) 9 volt batteries or the supplied 94-260 VAC, 50/60 Hz power adapter.

The instrument accurately measures resistance over a full 11 decade range from 10^1 to 10^{12} ohms with a total measurement accuracy better than ±5%. Three LED point source readouts indicate whether the measured resistance is within the selected range (continuous green light), under the selected range (flashing yellow light) or over the selected range (flashing red light). A pulsating audio tone is also provided to indicate out of range measurements. This tone can be switched on or off by the user.

The RANGE SELECT switch has two scales. The black scale indicates the actual measured resistance. The red scale indicates the calculated surface resistivity when using probes or test fixtures with a built-in X10 multiplication factor. The ETS Model 803 Series and 805 Resistivity Probes/Test Fixtures incorporate the x10 multiplication factor. The switch covers 10 decades from 10^2 to 10^{12} ohms, which corresponds to the green PASS indicator. The additional two decades are obtained by the meter which can measure one decade below and one decade above the green PASS range.

The measuring probes are connected to standard banana jacks located on the front panel of the instrument. A ground jack is also provided for those measurements requiring a grounded surface such as the measurement of surface resistivity of insulating materials as specified in ASTM D 257.

A 36" Teflon insulated shielded cable terminated with standard banana plugs is provided.

3.0 Operation

The Model 872 Wide Range Resistance Meter is an easy to use instrument for accurately measuring resistance/resistivity or indicating the acceptance or rejection of a measurement on a pass/fail basis. The instrument consists of four (4) controls. POWER, AUDIO, RANGE SELECT and VOLTAGE SELECT. The POWER switch turns the unit on, which is indicated by one of the RANGE LEDs illuminating. The AUDIO switch enables the user to disable the pulsating out-of-range audio indicator. The RANGE SELECT switch determines which resistance/resistivity decade will be indicated by the green PASS indicator. Th VOLTAGE SELECT switch enables the user to select either a 10 or 100 volt test voltage.

Plug the universal AC Power Module into a standard (94 – 240 volt) outlet if AC power is desired. The 16 volt DC power module is powered when it is plugged in. The POWER switch on the front panel turns the measuring electronics on and off. When the AC power module is used the batteries are disconnected. Standard 9 volt alkaline batteries are used.

Connect the desired measuring probe or test fixture to the red, black or green input connectors located on the front panel. The test voltage is applied to the red connector. If a ground connection is required, connect the GROUND jack on the rear panel to house ground.

Turn the unit on and select the desired test voltage and the desired resistance range by rotating the RANGE SELECT switch to the appropriate PASS range. If a specific resistance/resistivity measurement is desired the select switch should be set to a position that gives a reading in the green range on the meter. Measurements made in either the green or yellow ranges will meet the specified instrument accuracy. However, measurements made in the red range will not meet the accuracy requirements and should not be used.

When testing an unknown material always start with a TEST VOLTAGE of 10 volts. If the measured resistance is greater than 1×10^6 ohms, switch to 100 volts.

If the PASS/FAIL feature of the instrument is used, rotate the RANGE SELECT switch until the green PASS indicator lights. If a specific resistance/resistivity is not specified or required the switch should be set to the range corresponding to the upper limit specified for the material. Depending upon the type of measurement being made (point-to-point resistance, resistance to ground, surface resistivity, volume resistivity, etc.) place the test probe on the unknown material or install the unknown material into the test fixture or test cell and wait at least 10 seconds before taking a reading. A PASS indication will indicate that the material meets the specified resistance/resistivity requirements. If an upper limit PASS range is used, an UNDER range indication will also indicate acceptable material. If a more specific indication is required, rotate the selector switch until the green PASS LED lights. The user is cautioned, however, that for many conductive materials a lower resistance/resistivity limit is also specified.

The pulsating audible tone will sound whenever the indicated resistance/resistivity is either over or under the selected decade range. The tone can be disabled by the user if desired by placing the AUDIO switch in the OFF position.

The user is cautioned that when measuring high resistances (10^8 or greater) the measuring probe and associated interconnect cables become susceptible to external electrostatic fields. When making measurements in this range it is recommended that the operator step away during the 10 second measurement time.

4.0 Maintenance and Calibration

The Model 872 Wide Range Resistance Meter is a ruggedly constructed and reliable instrument and should be handled as any precision laboratory instrument is handled. The instrument contains no user serviceable parts and should be returned to the factory for repair.

To verify the performance of the Model 872 and to check the calibration of each range, a test set-up utilizing a total of twenty (20) precision 1% resistors of different values is required. Table 1 lists the resistor values required to check the calibration of each range. An incorrect indication of a particular resistor value tested in the appropriated range indicates that the range is out of tolerence.

Connect each resistor to the input banana jacks and measure the value using the meter. Note the PASS/FAIL LED indication. When measuring the higher ranges (above 10^7 ohms) lead dress and operator movement can affect the measurement. Utmost care should be exercised to minimize any erroneous indications.

An alternative calibration check can be performed by using several precision resistors of known value and comparing this value with the measurement obtained on the Model 872 Meter. However, this test will not check the PASS/FAIL thresholds.

Range	CAL Resistor Value	Indication			Notes
		Under	Pass	Over	
1.0×10^2	98 ohms	X			Use ¼ watt or larger
1.0×10^3 ohms	102 ohms		X		resistors for these tests.
	980 ohms		X		
	1.02K			X	
1.0×10^3	980 ohms	X			Allow at least 5 seconds
1.0×10^4 ohms	1.02 ohms		X		for indicators to stabilize.
	9.8K		X		
	10.2K			X	
1.0×10^4	9.8K	X			Allow at least 5 seconds
1.0×10^5 ohms	10.2K		X		for indicators to stabilize.
	98K		X		
	102K			X	
1.0×10^5	98K	X			Allow at least 5 seconds
1.0×10^6 ohms	102K		X		for indicators to stabilize.
	980K		X		
	1.02Meg			X	
1.0×10^6	980K	X			Allow at least 5 seconds
1.0×10^7 ohms	1.02Meg		X		for indicators to stabilize.
	9.8Meg		X		
	10.2Meg			X	
1.0×10^7	9.8Meg	X			Allow at least 10 seconds
1.0×10^8 ohms	10.2Meg		X		for indicators to stabilize.
	98Meg		X		
	102Meg			X	
1.0×10^8	95Meg	X			Allow at least 10 seconds
1.0×10^9 ohms	105Meg		X		for indications to stabilize.
	950Meg		X		
	1.05Gigohm			X	
1.0×10^9	950Meg	X			Allow at least 10 seconds
1.0×10^{10} ohms	1.05Gigohm		X		for indications to stabilize.
	9.5Gigohm		X		
	10.5Gigohm			X	
1.0×10^{10}	9.5Gigohm	X			Allow at least 10 seconds
1.0×10^{11} ohms	10.5Gigohm		X		for readings to stabilize.
	95Gigohm		X		
	105Gigohm			X	

5.0 WARRANTY

Electro-Tech Systems, Inc. warrants its equipment, accessories and parts of its manufacture to be and remain free from defects in material and workmanship for a period of one (1) year from date of invoice and will, at the discretion of Seller, either replace or repair without charge, F.O.B. Glenside, similar equipment or a similar part to replace any equipment or part of its manufacture which, within the above stated time, is proved to have been defective at the time it was sold. All equipment claimed defective must be returned properly identified to the Seller (or presented to one of its agents for inspection). This warranty only applies to equipment operated in accordance with Seller's operating instructions.

Seller's warranty with respect to those parts of the equipment which are purchased from other manufacturers shall be subject only to that manufacturer's warranty.

The Seller's liability hereunder is expressly limited to repairing or replacing any parts of the equipment manufactured by the manufacturer and found to have been defective. The Seller shall not be liable for damage resulting or claimed to result from any cause whatsoever.

This warranty becomes null and void should the equipment, or any part thereof, be abused or modified by the customer of if used in any application other than that for which it was intended. This warranty to replace or repair is the only warranty, either expressed or implied or provided by law, and is in lieu of all other warranties and the Seller denies any other promise, guarantee, or warranty with respect to the equipment or accessories and, in particular, as to its or their suitability for the purposes of the buyer or its or their performance, either quantitatively or qualitatively or as to the products which it may produce and the buyer is expected to expressly waive rights to any warranty other than that stated herein.

ETS must be notified before any equipment is returned for repair. ETS will issue an RMA (Return Material Authorization) number for return of equipment.

Equipment should be shipped prepaid and insured in the original packaging. If the original packaging is not available, the equipment must be packed in a sufficiently large box (or boxes if applicable) of double wall construction with substantial packing around all sides. The RMA number, description of the problem along with the contact name and telephone number must be included in formal paperwork and enclosed with the instrument. Round trip freight and related charges are the owner's responsibility.

WARNING

WOODEN CRATES MUST NOT BE USED. PACKAGING OF DELICATE INSTRUMENTS IN WOODEN CRATES SUBSTANTIALLY INCREASES THE CONTENT'S SUSCEPTIBILITY TO SHOCK DAMAGE. DO NOT PLACE INSTRUMENTS OR ACCESSORIES INSIDE OTHER INSTRUMENTS OR CHAMBERS. ELECTRO-TECH SYSTEMS, INC. WILL NOT ASSUME RESPONSIBILITY FOR ADDITIONAL COST OF REPAIR DUE TO DAMAGE INCURRED DURING SHIPMENT AS A RESULT OF POOR PACKAGING.

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Model 803B

Resistance/Resistivity Probe

Operating Instructions

Serial Number:_____

7/93
1/95 Rev
3/98 Rev

Electrostatic Instrumentation • ESD Testing Laboratory • Environmental Control

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1.0 INTRODUCTION

There exist many applications where the resistance and/or resistivity properties of insulating type materials are required. ANSI/ASTM is the standard test method for the measurement of "D.C. RESISTANCE OR CONDUCTANCE OF INSULATING MATERIALS". This test method covers direct-current procedures for determining the d-c insulation resistance, volume resistance, volume resisitivity, surface resistance and surface resistivity of electrical insulating materials.

ESD S11.11 - Surface Resistance Measurement of Static Dissipative Materials is the latest standard developed for evaluating static dissipative material. This test method is very similar to ASTM-D 257 except the resistance measured by a defined electrode configuration, test voltage and environmental conditions is specified in lieu of converting the resistance measured in to a normalized ohms per square.

One major application of the resistance/resistivity measurement is predicting the ability of dissipative and insulating type materials to dissipate a buildup of electrostatic charge. Materials that are coated, chemically treated or contain an internal antistatic agent have static dissipative characteristics that are a function of the surface resistance. On the other hand, materials that are loaded with a conductive material such as carbon, are usually volume conductive. In most cases a material that is volume conductive is also surface conductive but there are certain composites where this rule does not hold true.

During the development of new static dissipating materials or coatings, it is necessary to know the material resistance in order to predict the static dissipative characteristics. Likewise, it is also necessary to measure this parameter during the evaluation and qualification of existing materials where the expected resistance values are known.

In the static control field a number of military, industry and individual company standards exist that specify the surface and/or volume resistance and/or resistivity as a material specification requirement. Among these standards are Mil Std 883C, Mil-B-81705C, EIA-541 (formerly EIA-IS-5-A) and NFPA Code 99 (formerly NFPA 56A).

ANSI/ASTM D 257 describes several measurement techniques and measuring electrode types for determining resistivity. The ETS Model 803B Resistance/Resistivity Probe is a circular measuring electrode that is based around the concentric ring electrode design specified in the standard. This electrode configuration, shown in Figure 1-1, restricts the measurement path (surface resistance/resistivity) to just the area between the two concentric ring electrodes, thus eliminating measurement errors attributed to stray current paths such as those experienced with parallel bar electrodes.

ESD S11.11 specifies a probe configuration that is identical to the Model 803B Probe. When measuring resistance of material using this probe the measured value is recorded. If applicable, the equivalent surface resistivity value can be calculated by multiplying the measured resistance by 10.

Figure 1-1
Model 803B Resistance/Resistivity Probe

2.0 EQUIPMENT DESCRIPTION

2.1 Model 803B Resistance/Resistivity Probe Equipment Description

The Model 803B Resistance/Resistivity Probe is the latest addition to the ETS line of resistance/resistivity probes. These concentric ring probes incorporate a geometrical configuration that provides a X10 multiplication factor to the surface resistivity measurement. Earlier probes were capable of measuring only the surface resistivity of materials. The Model 803B Probe, however, is capable of measuring both the surface and volume resistance/resistivity of materials having relatively smooth flat surfaces of at least 2.5" diameter. The ability of the Model 803B Probe to measure materials of this size makes it compatible with the standard specimen size used in most electrostatic parameter evaluations.

The design of the Model 803B Probe electrode configuration is derived from the applicable formulas set forth in ANSI/ASTM D 257 (this also applies to ESD S11.11). For the concentric ring design the surface resistivity, ρ_s, is a function of the ratio between the inner and outer ring diameters as shown in the following formula:

$$s = \frac{(D_1 + D_2)}{(D_2 - D_1)} \qquad R_m \text{ ohms/square}$$

D_1 = Outside Diameter of inner ring
D_2 = Inner Diameter of outer ring
R_m = Measured resistance in ohms

By properly choosing D_1 and D_2, the factor $(D_1 + D_2)/(D_2 - D_1)$ can be made to equal any reasonable number. In the case of the Model 803B Probe, $(D_1 + D_2)/(D_2 - D_1)$ equals 10, resulting in a surface resistivity measurement of

$$\rho_s = 10\ R_m \text{ ohms/square}$$

The numeric value of ρ_s is actually in ohms. The designation ohms/square clarifies the number as a surface resistivity measurement.

While surface resistivity is basically a function of the ratio between the inner diameter of the outer electrode and the outer diameter of the inner electrode, the volume resistivity is basically a function of the area of the inner electrode and the thickness of the test specimen. When measuring surface resistivity, the test specimen is usually placed on a flat plane and the resistance between the plane and the center electrode measured. On the other hand, when measuring volume resistivity the resistance between the inner electrode and the flat plane (which is now the voltage electrode) is measured. For insulating material the outer electrode is grounded, thus becoming the guard electrode.

The volume resistivity, ρ_v, must always be calculated because the thickness of the test specimen is one of the measurement variables. The ANSI/ASTM D 257 formula for ρ_v is

$$\rho_v = \frac{A}{t} R_m \text{ ohms-cm}$$

A = Area of measuring electrode in cm^2
t = Thickness of test specimen in cm
R_m = Measured resistance in ohms

For the Model 803B Probe the area of the measuring electrode is 7.1 cm^2, hence

$$\rho_v = \frac{7.1 R_m}{t} \text{ ohms-cm}$$

The Model 803B Probe is fabricated from brass. The electrodes are mounted on Teflon insulators which provides high insulation resistance between the electrodes under relatively high humidity conditions. This construction results in a 5 pound probe measuring only 3.25" in diameter.

The electrode contact material is a high compliance silver impregnated silicon rubber with a hardness of 65 durometer which provides excellent probe/surface contact. For most materials, the need to apply additional pressure is eliminated. The resistance of the electrode contact material is less than 1 ohm which enables the probe to measure very low resistance material.

The Model 803B Resistance/Resistivity Probe comes complete with a 5" diameter flat plane and an acrylic insulated plane plus the necessary cables for connecting the probe to a resistance meter.

2.2 Model 803B Surface Resistance Test Fixture (Optional)

The Model 809B Surface Resistance Test Fixture is designed to check both the surface alignment of the ETS Model 803A Surface/Volume Resistivity Probe and the Model 803B Resistance/Resistivity Probe, conductive rubber electrodes and the time of electrification of the Probe - Cable Resistance Meter test set up at 1 Teraohm ($1x10^{12}$ ohms). In addition, the Test Fixture also allows the user to check the accuracy of the measuring instrument at both the upper and lower ends of the measuring range. This test fixture meets the requirements specified in ESD S11.11 "Surface Resistance Measurement of Dissipative Planer Materials."

A concentric ring surface resistance measurement set up measures the resistance of an infinite number of parallel resistances between the inner and outer electrodes. When both electrodes make perfect contact with the test surface, the resistance measured will be the minimum value obtainable. If total contact is not made then the measured resistance will read higher. The effect of inconsistant contact between the probe electrodes and the test material becomes quite significant at higher resistances.

A surface resistance measurement as defined in ESD S11.11 and a surface resistivity measurement are the resistances measured between two geometrically defined electrodes. Practical calibration of a surface resistance/resistivity test set up consists of maintaining the correct geometric configuration and ensuring total contact of the probe with the test surface and that the measuring instrument accurately indicates the correct resistance.

The Model 809B Surface Resistance Test Fixture now enables the user of the ETS Model 803A and 803B Probes to accurately verify the alignment of the electrodes, determine the electrification time for a $1x10^{12}$ ohm measurement, and to check the overall measurement accuracy of the test set up including the Probe, cables and measuring instrument.

The Model 809B Test Fixture consists of two (2) different resistor configurations. One side of the Test Fixture consists of twenty (20) points located equidistant between the inner and outer Probe electrode diameters. Connected between each pair of points is a 10 Megohm, 1% precision metal film resistor. Twenty (20), 10 Megohm resistors in parallel give a measured resistance of 0.50 Megohm ($0.5x10^{6}$ ohms). Therefore, when a properly aligned 803A or 803B Probe is placed in the test fixture, the measuring instrument should read $0.5x10^{6}$ ohms. Any reading above this number indicates that the Probe must be returned to the factory for recalibration. A correct reading also checks the measurement accuracy of the lower end of the desired measurement range.

The opposite side of the Test Fixture consists of an identical appearing test pad, however, all 20 pads on each ring are tied together and the rings are connected by a single $1x10^{12}$ (±5%) ohm resistor. When the Probe is placed on the text fixture and the excitation voltage (V_E) applied, the time for the resistance meter to read $1x10^{12}$ (±5%) ohms (time of electrification) can be determined. In addition, the accuracy of the measurement set up can be checked at the upper end of the desired measurement range.

2.3 Model 819 Volume Resistance Test Fixture (Optional)

The Model 819 Volume Resistance Test Fixture is designed to check the degree of flatness of the center conductive rubber electrode of the ETS Model 803A Surface/Volume Resistivity Probe and the Model 803B Resistance/Resistivity Probe.

Volume resistivity and volume resistance utilize two (2) flat electrodes placed on the top and bottom surfaces of the material to be measured. When both electrodes make perfect contact with the test surfaces the resistance measured will be the minimum obtainable. If total contact is not made then the measured resistance will read higher. The effect of inconsistant contact between the Probe electrodes and the test material becomes quite significant at higher resistances.

The Model 819 Volume Resistance Test Fixture now enables the user of the ETS Model 803A and 803B Probes to accurately verify the degree of surface contact between the Probe center electrode and a smooth flat surface.

The Test Fixture consists of a pattern of twenty (20) pads located symetrically over the area of the center electrode. Connected to each pad is a 10 Megohm, 1% metal film resistor. The other ends are tied together and connected to a common banana jack. Twenty (20), 10 Megohm resistors in parallel give a measured resistance of 0.5 Megohm ($0.5x10^6$ ohms). Therefore, a uniform center electrode surface will make contact with all twenty (20) pads and give an indicated resistance reading of 0.5 Megohms ($0.5x10^6$ ohms). Any reading above this number indicates that the Probe is out of calibration.

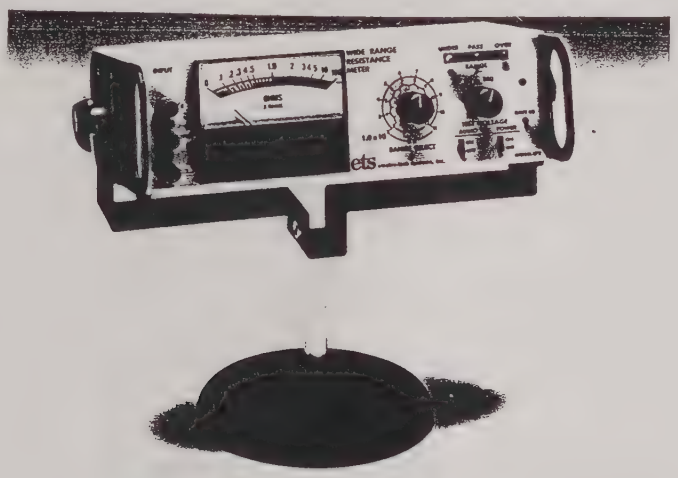
3.0 OPERATION

3.1 Instrumentation

The Model 803B Resistance/ Resistivity Probe can be used with any ohmmeter or resistance measuring apparatus that is capable of measuring within the desired resistance range. The Probe has three standard banana jacks for connection to the measuring instrument. The Inner and Outer electrodes are connected via standard black and red banana jacks respectively. A third banana jack, installed on the outer shell of the Probe, is a grounding connector. The following are two instruments offered by ETS to perform the desired measurements with the Model 803B Probe:

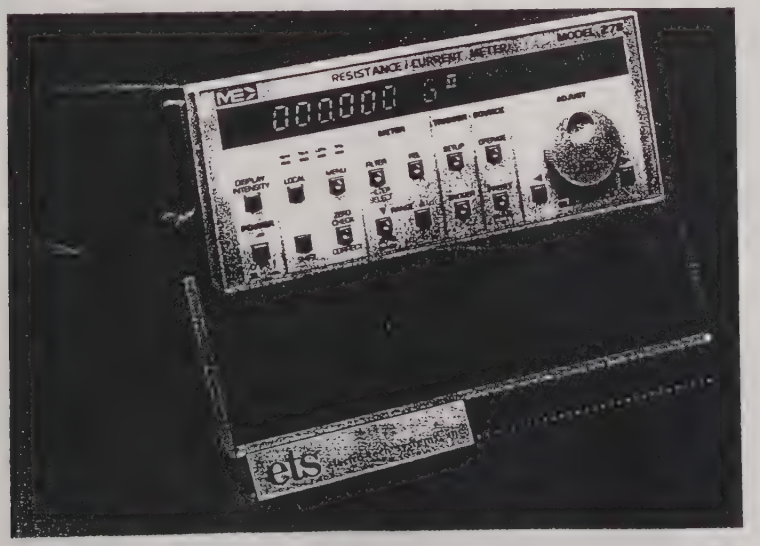
3.1.1 ETS Model 872 Wide Range Resistance Meter

This instrument is capable of measuring resistance in the range of 10 ohms to 10^{12} ohms with a test voltage of 10 volts and 10^4 to 10^{12} ohms with a test voltage of 100 volts. This meter, shown in Figure 3-1 has an analog meter readout and PASS/FAIL indicators when measurements fall out of the decade selected by the user. A regulated power supply provides user selectable test voltages of 10 and 100 volts. The instrument has direct reading scales for resistance and resistivity utilizing the ETS Model 803B Probe. Measurement accuracy is ±2% over the 10^1 - 10^7 ohms range and better than 5% over the 10^8 to 10^{10} ohm range.



3.1.2 ETS Model 863/278 Precision Resistance/Current Meter

This microprocessor based instrument is capable of measuring resistances over the range of 0.5 ohms to $50x10^{15}$ ohms using test voltages ranging from 0.01 to 500 volts. The accuracy of this instrument is better than 0.5% between 10^3 and 10^{12} ohms. Resistance is displayed on a 10-character LED readout. This instrument is shown in Figure 3-2.



3.2 Equipment Set-up

3.2.1 Surface Resistivity

Figure 3-3 shows a typical Model 803B probe hookup to resistance meter for measuring surface resistivity. (If using the Dr.Thiedig MILLI-TO-2 Wide Range Resistance Meter the special shielded teflon sense cable is connected to the Inner electrode (Black Jack) and the voltage cable is connected to the Outer electrode (Red Jack).) If used, the ground plane is connected to the ground on the meter. Also the outer shell of the 803B Probe is connected to ground. (This ground connection is not necessary for resistivity measurements less than 10^9 ohms/square).

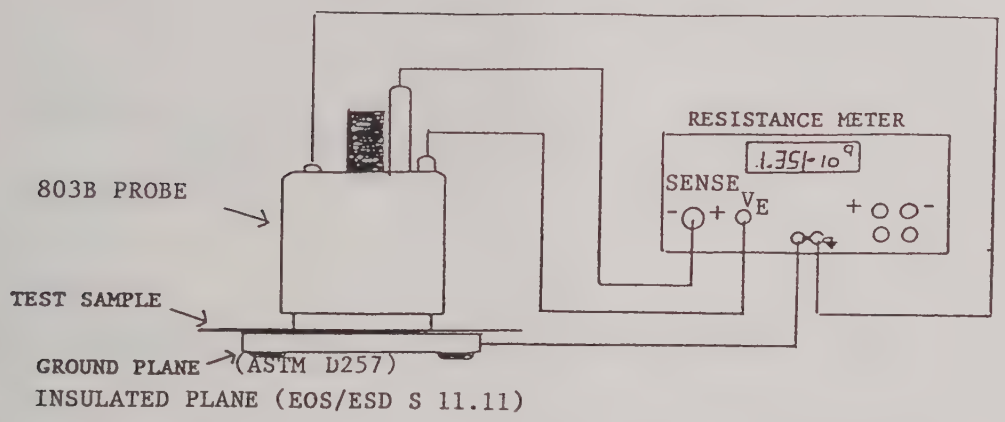


Figure 3-3
803B Probe/Resistance Meter Hookup
for Surface Resistance/Resistivity Measurement

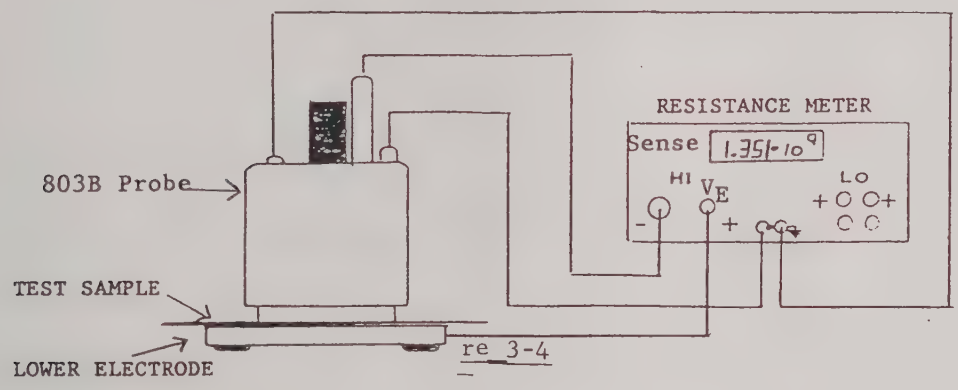
(If using a Dr. Thiedig Meter, the cables are connected to the HIGH RANGE input when resistances greater than $5x10^4$ ohms are to be measured. The cables are connected to the LOW RANGE input when resistances less than 10^5 ohms are to be measured.)

For the other meters follow the instructions provided by the respective meter manufacturer.

If a meter with only two output connections is used, connect the - side to the Inner electrode and the + side to the Outer electrode.

3.2.2 Volume Resistivity

Figure 3-4 shows a typical Model 803B Probe hookup to a resistance meter for measuring volume resistivity. If using the MILLI-TO-2 Meter the special shielded teflon sense cable is connected to the Inner electrode (Black Jack) and the voltage cable is connected to the plate (Ground plane for surface resistivity). The Outer electrode (Black Jack) is connected to ground along with the outer shell of the Probe.



re 3-4

Figure 3-4
803B Probe/Resistance Meter Hookup for Volume Resistivity Measurement

The other hookup requirements discussed in Section 3.2.1 also apply to the volume resistivity measurement.

3.3 Measurement of Surface Resistance, Rm/Resistivity, $_s$

3.3.1 Material Considerations

The Model 803B Probe will accurately measure the surface resistance/resistivity of virtually any smooth surface that is greater than 2.5" in diameter. For most film and foam materials the standard 5 pound probe weight is sufficient for the electrodes to make total contact with the material surface. For rigid materials, such as table tops, plastics, cardboard, etc., additional force may have to be applied to the Probe to ensure total contact. Microscopically these surfaces are generally not smooth and are uneven as illustrated in Figure 3-5.

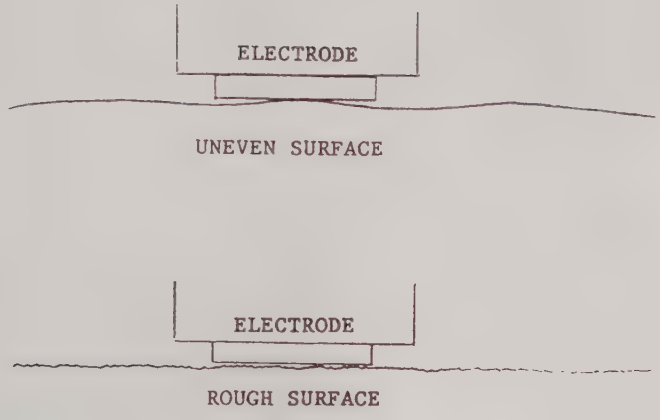


Figure 3-5
Microscopic Electrode/Rigid Surface Contact

In most cases, the application of additional pressure will cause the measured resistance reading to decrease. This is a result of both lower contact resistance and the total electrode/surface contact area (greater number of parallel resistance paths).

Another area that must be considered when attempting to make a surface resistivity measurement is the composition of the material being evaluated. The materials defined in ANSI/ASTM D 257 are homogeneous, insulating types. However, many materials are nonhomogeneous and relatively conductive. ESD S11.11 should be used as the test standard for measuring the surface resistance of materials in the range of 10^4 to 10^{11} ohms. (In resistivity terminology 10^5-10^{12} ohms/sq.

When measuring insulating type homogeneous materials the ground plane guards against stray current paths that may cause measurement errors. However, materials having relatively low volume resistivities cannot be measured using this technique. Instead of the current path between the two electrodes being only across the top surface it is also through the material to ground. This creates a voltage divider network which results in a surface resistivity measurement that will be higher than that obtained without the ground plane. This problem distorts the ASTM-D 257 measurement resulting in large errors. EOS/ESD Std. 11.11 addresses this problem and should be used to evaluate these types of material.

A similar problem exists with materials that are coated with, or laminated to, a conductive surface. In this case the excitation voltage is not divided down because the conductive layer is floating, but the conductive layer now becomes a parallel resistance path to the surface being measured. The surface resistance may actually be very high but the measured resistance will be that of the surface resistance path between the two electrodes in parallel with the series combination of the two volume conductive paths and the conductive layer as shown in Figure 3-6.

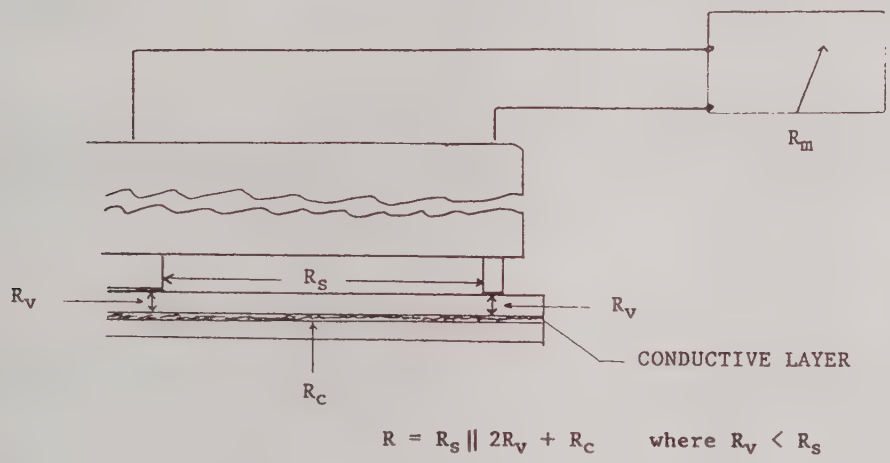


Figure 3-6
Resistance Path of Laminated Materials

For these materials, ESD S11.11 should be used.

Another material type is the composite. These materials generally consist of a high resistance resin loaded with conductive fibers. The surface resistivity of these materials is essentially nonmeasurable. What is actually being measured is the net resistance of the series/parallel combination of the conductive fibers connecting the Inner and Outer electrodes. A common problem that exists with this material is when the fibers are buried just below the surface. The top surface appears as a high resistance. When the excitation voltage is increased to measure this high resistance, the dielectric of the top surface breaks down and the meter then reads overscale.

The above precautions are presented to make the user aware of the complexity in making a surface resistance or resistivity measurement. It is not simply placing a probe onto a surface and reading a meter. With care, many different types of materials can be evaluated but again, the user is cautioned that the reading obtained may not be the true surface resistivity defined in ANSI/ASTM D 257, even though a specification may specify ASTM D 257 as the required test method.

3.3.2 Measuring Considerations

3.3.2.1 Time of Electrification

In the previous section the effect of contact pressure (which actually changes the contact area) on the measuring accuracy was discussed. Another very important consideration that many times is ignored is what is referred to as the "time of electrification". In simple terms the time of electrification is the time for the current to flow between the measuring electrodes. All materials have, in basic terms, some capacitance. When measuring low resistances this capacitance is negligible in relation to the resistance of the material. Therefore, the current flow becomes restricted by the resistance of the material only.

On the other hand, for high resistance measurements current flow is controlled by both the resistance and capacitance of the material. The resistance does not begin to dominate the measurement until the exponential charging of the material capacitance has been completed. The time constant, τ , is expressed as

$$\tau = RC$$

For total charging, five time constants (5τ) is the accepted norm. Therefore, if a material has a capacitance of 1 picofarad and a resistance of $1x10^{12}$ ohms, $\tau = RC = (1x10^{12})(1x10^{-12}) = 1$ second and the total charging time, $t = 5\tau = 5$ seconds. This is the time of electridication. It is seen that if the capacitance is only a few picofarads the time of electrification can stretch out to many seconds. Figure 3-7 illustrates the time of electrification of an insulating type material.

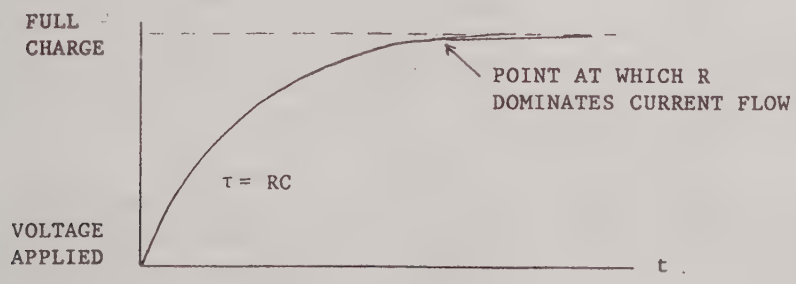


Figure 3-7
Time of Electrification

Resistances that are measured before the full time of electrification has occurred will appear to be less than the actual resistance of the surface. This difference can be several orders of magnitude. ASTM D 257 recommends a time of electrification of 60 seconds, but in many measurements a shorter time may be used or a longer time may be required. Usually for small specimens with resistances less than 10^{10} ohms, an electrification time of 10 to 15 seconds is sufficient or the point at which the resistance measurement stabilizes. On the other hand with large surfaces, such as table tops, the capacitance is relatively large and 60 seconds may not be long enough. Here, the user may either wait for the complete electrification and obtain a true resistance measurement or specify the measurement at the 60 second electrification time point for a relative resistance measurement. ESD S11.11 specifies the method for determining the electrification of the test set-up used. The optional ETS Model 809B is used for this purpose.

In any case the time of electrification is a critical parameter in the measurement of resistance and resistivity and must be taken into account if meaningful results are to be obtained.

3.3.2.2 Test Voltage, V_E

Certain materials are voltage dependent, that is, the resistance measured at one excitation voltage will not be the same as that measured with a different voltage. Generally, test voltages of 100, 500 and 1000 volts are used for very high resistances (10^9 ohms and above) while test voltages of 10, 20, 50 and 100 are used for lower resistances in the range of 10^3 to 10^{12} ohms. Some instruments use a single voltage to cover a wide resistance range of 10^3 to 10^{12} ohms. ESD S11.11 specifies a test voltage of 100 volts for resistances between 10^6 and 10^{11} ohms and 10 volts for resistances between 10^4 and 10^6 ohms.

Another consideration is the contact resistance between the Probe electrodes and the material surface. For certain materials, especially those in the lower resistance range ($<10^6$ ohms), the contact resistance can be a factor. At low ranges test voltages below 10 volts is used. This low voltage may not be sufficient to break down the contact resistance. Hence, a significant difference in measured resistance may be obtained using different test voltages.

When establishing resistance and resistivity requirements or when comparing resistance and resistivity measurements, the user must specify the test voltage. Failure to do so could result in large measurement differences between different test set-ups.

3.3.2.3 Measurement Procedure

The above information is provided to enable the user to make meaningful and accurate resistance and resistivity measurements with the Model 803B Probe.

The following is a recommended procedure to be followed when measuring surface resistivity:

1. Determine the type of material being measured. Use the precautions described in the previous sections. Use ASTM D 257 only when measuring insulating material; otherwise, use ESD S11.11.

2. Make certain the contact electrodes are clean. The electrodes may be cleaned with Isopropyl alcohol.

3. Place the Probe firmly on the surface to be measured. If the material to be tested is a film or a foam, additional pressure should not be required.

4. Select the appropriate test voltage and resistance range scale.

5. Observe the meter reading. If it is unstable or the test material is rigid, apply pressure to the Probe. If the meter reading decreases, continue to apply additional pressure until the reading stabilizes.

6. If the meter reading remains stabilized for several seconds, record the reading.

7. If the meter reading continues to slowly increase, wait until it stabilizes or for one minute before taking a reading.

8. Repeat the above measurement procedure at different locations across the material surface.

9. If testing to ESD S11.11 the measurement in ohms is the value recorded.

10. The surface resistivity is then just 10 times the measured resistance ($\rho_s = 10\ R_m$).

3.4 Measurement of Volume Resistivity, $_v$

The same parameters, electrode contact pressure, time of electrification, excitation voltage and material composition must also be taken into consideration when measuring the volume resistivity, $_v$, of materials.

The volume resistivity of a material is defined as the resistance through a one cubic centimeter of material. The user is cautioned that a relatively low resistance measured through a very thin film may actually describe a material with a very high volume resistivity.

To measure the volume resistivity of a material the same testing procedure described in Section 3.3.2.3 should be followed to measure the volume resistance. To obtain the volume resistivity, the thickness of the test material must be measured using a metric micrometer or converting the English measurement to metric (1 mil = 2.54×10^{-3} cm). The volume resistivity using the Model 803B Probe is then

$$\rho v = \frac{7.1}{t} R_m \text{ ohms-cm}$$

3.5 Other Applications

The Model 803B Probe can be used in other applications such as the checking of the surface resistance to ground. In this application one side of the ohmmeter is connected to the Inner electrode (Red banana jack) and the other side to ground.

4.0 MAINTENANCE

The Model 803B Surface/Volume Resistivity Probe is a precision instrument and should be handled as such. The alignment of the Inner and Outer electrodes is critical to ensure total surface contact. The silicon rubber contact material is impregnated with silver to obtain low contact resistance. The user must ensure that the contact area is clean and free of contaminents prior to making a measurement. Also, the Probe should not be exposed to atmospheres or surfaces that may corrode the silver particles. If exposure is necessary, the contacts should be cleaned with Isopropyl alcohol immediately after use.

When not in use the Probe should be kept on a flat smooth surface such as the flat plane. The Probe should never be kept on a sharp or protruding object since this may damage or put a set in the silicon electrodes.

If the contact electrodes are damaged or the Probe knocked out of alignment, the unit must be returned to ETS for repair. The Probe does not contain any user replaceable parts.

The optional ETS Model 809B Surface Resistance Test Fixture and the Model 819 Volume Resistance Test Fixture provides a means of periodically verifying the calibration of the Model 803B Probe.

APPENDIX A

WARRANTY

Electro-Tech Systems, Inc. warrants its equipment, accessories and parts of its manufacture to be and remain free from defects in material and workmanship for a period of one (1) year from date of invoice and will, at the discretion of Seller, either replace or repair without charge, F.O.B. Glenside, similar equipment or a similar part to replace any equipment or part of its manufacture which, within the above stated time, is proved to have been defective at the time it was sold. All equipment claimed defective must be returned properly identified to the Seller (or presented to one of its agents for inspection). This warranty only applies to equipment operated in accordance with Seller's operating instructions.

Seller's warranty with respect to those parts of the equipment which are purchased from other manufacturers shall be subject only to that manufacturer's warranty.

The Seller's liability hereunder is expressly limited to repairing or replacing any parts of the equipment manufactured by the manufacturer and found to have been defective. The Seller shall not be liable for damage resulting or claimed to result from any cause whatsoever.

This warranty becomes null and void should the equipment, or any part thereof, be abused or modified by the customer of if used in any application other than that for which it was intended. This warranty to replace or repair is the only warranty, either expressed or implied or provided by law, and is in lieu of all other warranties and the Seller denies any other promise, guarantee, or warranty with respect to the equipment or accessories and, in particular, as to its or their suitability for the purposes of the buyer or its or their performance, either quantitatively or qualitatively or as to the products which it may produce and the buyer is expected to expressly waive rights to any warranty other than that stated herein.

ETS must be notified before any equipment is returned for repair. ETS will issue an RMA (Return Material Authorization) number for return of equipment.

Equipment should be shipped prepaid and insured in the original packaging. If the original packaging is not available, the equipment must be packed in a sufficiently large box (or boxes if applicable) of double wall construction with substantial packing around all sides. The RMA number, description of the problem along with the contact name and telephone number must be included in formal paperwork and enclosed with the instrument. Round trip freight and related charges are the owner's responsibility.

WARNING

WOODEN CRATES MUST NOT BE USED. PACKAGING OF DELICATE INSTRUMENTS IN WOODEN CRATES SUBSTANTIALLY INCREASES THE CONTENT'S SUSCEPTIBILITY TO SHOCK DAMAGE. DO NOT PLACE INSTRUMENTS OR ACCESSORIES INSIDE OTHER INSTRUMENTS OR CHAMBERS. ELECTRO-TECH SYSTEMS, INC. WILL NOT ASSUME RESPONSIBILITY FOR ADDITIONAL COST OF REPAIR DUE TO DAMAGE INCURRED DURING SHIPMENT AS A RESULT OF POOR PACKAGING.

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